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State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

WATER QUALITY CRITERIA FOR DIAZINON AND CHLORPYRIFOS

OFFICE OF SPILL PREVENTION AND RESPONSE
Administrative Report 00-3
2000

WATER QUALITY CRITERIA FOR DIAZINON AND CHLORPYRIFOS

by

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SUMMARY

Recent toxicity information was reviewed and used to update freshwater and saltwater aquatic life criteria for diazinon and chlorpyrifos. These water quality criteria were compared to criteria developed by the U.S. Environmental Protection Agency (USEPA 1986;1998). The joint toxicity of diazinon and chlorpyrifos was also evaluated.

Thirteen new tests on the acute toxicity of diazinon to aquatic organisms were evaluated and 12 were accepted. These new values were pooled with values previously evaluated (Menconi and Cox 1994). The freshwater Final Acute Value (FAV) for diazinon was 0.16 µg/L. The freshwater Criterion Maximum Concentration (CMC) for diazinon was 0.08 µg/L. The draft CMC proposed by USEPA (1998) was 0.09 µg/L. No saltwater acute or chronic criteria were developed due to inadequate data. Six tests on the chronic toxicity of diazinon to aquatic organisms were evaluated and five were accepted. The freshwater Final Chronic Value (FCV) for diazinon was 0.05 µg/L. The freshwater Criterion Continuous Concentration (CCC) for diazinon was 0.05 µg/L. The USEPA (1998) did not propose a FCV or CCC for diazinon.

Twenty-five new tests on the acute toxicity of chlorpyrifos to aquatic organisms were evaluated and 13 were accepted. These new values were pooled with values previously evaluated (Menconi and Paul 1994). The freshwater FAV for chlorpyrifos was 0.05 µg/L. The freshwater CMC for chlorpyrifos was 0.02 µg/L. The freshwater CMC calculated by USEPA (1986) was 0.083 µg/L. The saltwater FAV for chlorpyrifos was 0.03 µg/L. The saltwater CMC was 0.02 µg/L. The saltwater CMC calculated by USEPA (1986) was 0.011 µg/L. One chronic toxicity test for chlorpyrifos was reviewed and accepted. The freshwater and saltwater FCVs for chlorpyrifos were 0.014 and 0.009 µg/L, respectively. The freshwater and saltwater CCCs for chlorpyrifos were 0.014 and 0.009 µg/L, respectively. Freshwater and saltwater CCCs calculated by USEPA (1986) were 0.041 and 0.0056 µg/L, respectively.

Two studies on the joint toxicity of diazinon and chlorpyrifos to cladoceran *Ceriodaphnia dubia* were evaluated. Both studies suggest that the toxicities of diazinon and chlorpyrifos were additive.

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LIST OF ACRONYMS

ACR:	Acute-Chronic Ratio
ASTM:	American Society for Testing and Materials
CCC:	Criterion Continuous Concentration
CDFG:	California Department of Fish and Game
CDPR:	California Department of Pesticide Regulation
CMC:	Criterion Maximum Concentration
CVRWQCB:	Central Valley Regional Water Quality Control Board
FACR:	Final Acute-to-Chronic Ratio
FAV:	Final Acute Value
FCV:	Final Chronic Value
FPV:	Final Plant Value
FRV:	Final Residue Value
GMAV:	Genus Mean Acute Value
LOEC:	Lowest Observable Effect Concentration
MATC:	Maximum Acceptable Toxicant Concentration
NOEC:	No Observable Effect Concentration
SMAV:	Species Mean Acute Value
USEPA:	U.S. Environmental Protection Agency
WQC:	Water Quality Criterion

ACKNOWLEDGMENTS

This assessment was funded by Interagency Agreement B81615 from CALFED. We appreciate the comments on this document from the California Department of Pesticide Regulation, Central Valley Regional Water Quality Control Board, and U.S. Environmental Protection Agency.

INTRODUCTION

Several agencies (U.S. Geological Survey, Central Valley Regional Water Quality Control Board (CVRWQCB), and California Department of Pesticide Regulation (CDPR)) have detected diazinon and chlorpyrifos in the waters of the Sacramento-San Joaquin watershed beginning in the early 1990s. These detections have been the result of runoff from agricultural and urban areas (Domagalski et al. 1997; Kuivila and Foe 1995; Kratzer 1998; Ross et al. 1996). The California Department of Fish and Game (CDFG) had previously assessed the effects of diazinon and chlorpyrifos on aquatic organisms in the Sacramento-San Joaquin watershed (Menconi and Cox 1994; Menconi and Paul 1994). CDFG's hazard assessments are based on data from accepted tests and procedures outlined in U.S. Environmental Protection Agency (USEPA 1985) guidelines (Appendix A). However, data gaps were present which allowed only calculation of interim water quality criteria (WQC). In addition, more data were needed to evaluate the effect (i.e., antagonism, additivity, or synergism) of the joint action of diazinon and chlorpyrifos on aquatic organisms. This report gives an updated summary of the toxicity database of diazinon and chlorpyrifos, both alone and in mixtures, to aquatic organisms.

ACUTE TOXICITY OF DIAZINON TO AQUATIC ORGANISMS

Thirteen new tests on the acute toxicity of diazinon to aquatic organisms were evaluated (Appendix B). Twelve of these tests were found to be in general conformance with acceptability criteria developed by the USEPA (1985) and American Society for testing and Materials (ASTM 1996). Five of the ten accepted tests were on saltwater organisms. The remaining five accepted freshwater tests were used to revise WQC previously generated (Menconi and Cox 1994). For the previously generated acute WQC (Menconi and Cox 1994), fifty-nine tests were evaluated, and thirty-four tests were accepted (Appendix C). The Genus Mean Acute Values (GMAVs) for diazinon were calculated using all data; and these were ranked in ascending order (Table 1). The new freshwater toxicity tests evaluated for this report were for cladoceran *Ceriodaphnia dubia* (three tests), fathead minnow *Pimephales promelas*, and snail *Physa sp.* Data from eight freshwater families recommended by USEPA (1985) were available to derive a freshwater Final Acute Value (FAV) of 0.16 µg/L (Table 2). The freshwater FAV previously calculated using seven of the eight families was 0.16 µg/L (Menconi and Cox 1994). The freshwater FAV calculated by USEPA (1998) was 0.1826 µg/L.

Acceptable data were available for four of the eight saltwater families recommended by USEPA (1985) (Tables 3 and 4). A saltwater FAV was not calculated.

Table 1. Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on freshwater species used to calculate the freshwater FAV for diazinon.

Rank	GMAV (µg/L)	Species	Number of tests
1	0.20	Amphipod	
		Gammarus fasciatus	1
2	0.44	Cladoceran	
		Ceriodaphnia dubia	7
3	1.06	Cladoceran, Genus *Daphnia*	
		Daphnia pulex (SMAV = 0.78)	3
		Daphnia magna (SMAV = 1.44)	2
4	1.59	Cladoceran	
		Simocephales serrulatus	2
5	4.15	Mysid	
		Neomysis mercedis	2
6	4.41	Snail	
		Physa sp.	1
7	25	Stonefly	
		Pteronarcys californica	1
8	272	Bluegill	
		Lepomis macrochirus	2
9	441	Salmonid, Genus *Oncorhynchus*	
		Oncorhynchus clarki (SMAV = 2166)	2
		Oncorhynchus mykiss (SMAV = 90)	3
10	660	Char, Genus *Salvelinus*	
		Salvelinus namaycush (SMAV = 602)	1
		Salvelinus fontinalis (SMAV = 723)	3
11	800	Guppy	
		Poecilia reticulata	1
12	1,643	Flagfish	
		Jordanella floridae	2
13	7,804	Fathead minnow	
		Pimephales promelas	5
14	8,000	Zebrafish	
		Brachydanio rerio	1
15	29,220	Rotifer	
		Brachionus calyciflorus	1

Table 2. Eight families of freshwater aquatic animals recommended by USEPA (1985) for use in deriving the Final Acute Value (FAV) and representative species for which diazinon acute toxicity data were available.

Family	Animal
1. One Salmonid	Brook trout
2. Another family in Osteichthyes	Bluegill
3. Another family in Chordata	Fathead minnow
4. One family not in Arthropoda or Chordata	Snail
5. One insect family or any phylum not already represented	Rotifer
6. One planktonic crustacean	Cladoceran
7. One benthic crustacean	Amphipod
8. One insect	Stonefly

Table 3. Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on saltwater species for diazinon.

Rank	GMAV (µg/L)	Species	Number of tests
1	5.6	Mysid	
		Mysidopsis bahia	3
2	21	Pink shrimp	
		Penaeus duorarum	1
3	28	Rotifer	
		Brachiomus plicatilis	3
4	880	Eastern oyster	
		Crassostrea virginica	1

Table 4. Eight families of saltwater aquatic animals recommended by USEPA (1985) for use in deriving the Final Acute Value (FAV) and representative species for which diazinon acute toxicity data were available.

Family	Animal
1, 2. Two families in chordata	N/A
	N/A
3. One family not in phylum Arthropoda or Chordata	Eastern oyster
4.5,6. Three other families not in phylum Chordata	Pink shrimp
	N/A
	N/A
7. A mysid or penaeid	Mysid
8. One other family not already represented	Rotifer

CHRONIC TOXICITY OF DIAZINON TO AQUATIC ORGANISMS

Six new chronic toxicity tests for diazinon were evaluated and five tests were accepted (Appendix B). The accepted tests were for cladoceran *Ceriodaphnia dubia*, sheepshead minnow *Cyprinodon variegatus*, mysid *Mysidopsis bahia*, and fathead minnow *Pimephales promelas* (two tests). An Acute-Chronic Ratio (ACR) value was generated for *C. dubia* using acute and chronic values from the same study (Table 5). There was no corresponding acute test for *C. variegatus*, so no ACR could be calculated. An ACR had previously been calculated for *M. bahia*, using acute and chronic values from the same study (Menconi and Cox 1994). For calculating the ACR, it is preferable to use acute and chronic values from the same study or at least the same laboratory. Therefore, the more recent chronic value for *M. bahia* was not used in the calculation of the ACR. An ACR had already been calculated for *P. promelas* (Menconi and Cox 1994). However, a new species mean ACR value was calculated using two sets of acute and chronic tests conducted in the same laboratory. The new species mean ACR for *P. promelas* was 196.

ACR values were calculated by dividing the FAV by the Maximum Acceptable Toxicant Concentration (MATC) for each species. Five ACR values were available for use in calculating the Final ACR (FACR) (Table 5). However, USEPA (1985) guidelines specify that if ACR values increase with increasing Species Mean Acute Values (SMAVs), only ACR values for those species with SMAVs close to the FAV should be used. It does appear that ACR values are lower for species acutely sensitive to diazinon. Therefore, only values for the three acutely sensitive species (*C. dubia*, *M. bahia*, and *D. magna*) were used in the calculation of the FACR. The calculated FACR was 3. The Final Chronic Value (FCV) is 0.05 μg/L. Most organophosphate insecticides have low FACR values based on the ACR values of acutely sensitive species. The FACR values for methyl parathion (Menconi and Harrington 1992) and chlorpyrifos (Menconi and Paul 1994) were 2.2 and 4, respectively.

Table 5. Available chronic tests and corresponding acute values and Acute-Chronic Ratio (ACR) values.

Species	Reference	MATC (μg/L)	LC_{50}(μg/L)	ACR
Cladoceran *Ceriodaphnia dubia*	Norberg-King (1987)	0.34	0.57	1.7
Cladoceran *Daphnia magna*	Surprenant (1988c)	0.23	1.44[a]	6.3
Fathead minnow *Pimephales promelas*	Norberg-King (1989)	25.0	9,350[b]	374
Fathead minnow *Pimephales promelas*	Jarvinen and Tanner (1982)	67	6,900[c]	103
Fathead minnow *Pimephales promelas*	Surprenant (1988d)	125	N/A[d]	N/A
Mysid *Mysidopsis bahia*	Nimmo et al. (1981)	1.9	4.82[c]	2.5
Mysid *Mysidopsis bahia*	Sousa et al. (1997a)	0.31	N/A	N/A
Sheepshead minnow *Cyprinodon variegatus*	Sousa et al. (1997b)	5.9	N/A	N/A

[a]Species Mean Acute Value: geometric mean of values from several tests on this species.
[b]Acute and chronic tests performed by the same laboratory.
[c]LC_{50} and MATC values from same test.
[d]Not Available. No corresponding acute value was available.

The USEPA (1998) did not calculate an FCV because they felt there was not a clear relationship between SMAVs and ACR values in their data set. When there is no trend apparent between SMAVs and ACR values and the ACR values are not within a factor of ten, USEPA (1985) guidelines specify that no chronic values can be calculated. Although there is overlap between the data sets for diazinon used by USEPA and CDFG, there are also several studies used in one report but not the other (Table 6). This difference is partially due to some studies being available to CDFG but not USEPA. Also, a few chronic studies that were accepted by the USEPA were rejected by DFG because the concentrations tested were inappropriate to generate Lowest Observable Effect Concentration (LOEC) and No Observable Effect Concentration (NOEC) values.

Table 6. Comparison of chronic toxicity tests for diazinon used by CDFG and USEPA

Reference	Organism	Used by USEPA?	Used by CDFG?	Comments
Allison (1977)	*Jordanella floridae*	Yes	No	Test rejected by CDFG because it did not generate an NOEC.
Allison and Hermanutz (1977)	*Salvelinus fontinalis*	Yes	No	Test rejected by CDFG (1994) because it did not generate an NOEC.
Goodman et al. (1979)	*Pimephales promelas*	Yes	No	Test rejected by CDFG (1994) because it did not generate an NOEC.
Jarvinen and Tanner (1982)	*Pimephales promelas*	Yes	Yes	
Nimmo et al. (1981)	*Mysidopsis bahia*	Yes	Yes	USEPA used original data to recalculate values; CDFG (1994) used values calculated by authors.
Norberg-King (1989)	*Pimephales promelas*	Yes	Yes	
Norberg-King (1987)	*Ceriodaphni a dubia*	Yes	No	Study not available to CDFG (cited in internal USEPA memo)
Surprenant (1988c)	*Daphnia magna*	No	Yes	Study not evaluated by USEPA, but accepted by CDFG (1994).

CRITERIA FOR DIAZINON

The freshwater FAV for diazinon was 0.16 µg/L. The FACR for diazinon was 3. The FCV for diazinon was 0.05 µg/L . The USEPA guidelines specify that a WQC consists of two concentrations, the Criterion Maximum Concentration (CMC) and the Criterion Continuous Concentration (CCC). The CMC was equal to one-half the FAV or 0.08 µg/L (Table 7). Freshwater organisms should not be affected unacceptably if the one-hour average concentration of diazinon does not exceed 0.08 µg/L more than once every three years on the average. The CCC is equal to the lowest of three values: the FCV, the Final Plant Value (FPV), of the Final Residue Value (FRV). Diazinon does not appear to bioconcentrate to a significant degree (Kanazawa 1978), and diazinon is more toxic to animals than to plants. Therefore, the CCC was equal to the FCV of 0.05 µg/L. Freshwater organisms should not be affected unacceptably if the four-day average concentration for diazinon does not exceed 0.04 µg/L more than once every three years on average. WQC are for diazinon alone.

Table 7. CDFG and USEPA (1998) water quality criteria for diazinon to freshwater organisms.

Reference	CMC	CCC
CDFG (this report)	0.08 µg/L	0.05 µg/L
USEPA (1998)	0.09 µg/L	not calculated

ACUTE TOXICITY OF CHLORPYRIFOS TO AQUATIC ORGANISMS

Twenty-five new tests on the acute toxicity of chlorpyrifos to aquatic organisms were evaluated (Appendix B). Thirteen of these tests were found to be in general conformance with acceptability criteria adapted from the USEPA (1985) and ASTM (1996). Three of the thirteen accepted tests were on saltwater organisms. The remaining ten accepted freshwater tests were used to revise freshwater WQC previously generated (Menconi and Paul 1994). For the previously generated acute WQC (Menconi and Paul 1994), one hundred and nine tests were evaluated, and seventy were accepted (Appendix D). GMAVs for chlorpyrifos were calculated using data from Menconi and Paul (1994) and more recent data; and these are ranked in ascending order (Table 8). The new freshwater toxicity tests evaluated for this report were for cladocerans *Ceriodaphnia dubia* (3 tests) and *Daphnia pulex*, amphipod *Hyalella azteca*, fathead minnow *Pimephales promelas* (2 tests), and midge *Chironomus tentans* (3 tests). Data from all eight freshwater families recommended by USEPA (1985) were available to derive a freshwater FAV (Table 9). The calculated freshwater FAV was 0.05 µg/L. The freshwater FAV previously calculated was 0.07 µg/L (Menconi and Paul 1994). The freshwater FAV calculated by USEPA (1986) was 0.1669 µg/L. The freshwater FAV calculated by Menconi and Paul (1994) and this report used toxicity values for sensitive species not available for use in the USEPA (1986) criteria.

GMAVs for saltwater organisms were calculated using all data and ranked in ascending order (Table 10). Acceptable data were available for all eight saltwater taxa (Table 11). The calculated saltwater FAV was 0.03 µg/L. This value is the same as the previously calculated FAV (Menconi and Paul 1994). The saltwater FAV calculated by USEPA (1986) was 0.02284 µg/L.

Table 8. Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on freshwater species used to calculate the freshwater FAV for chlorpyrifos.

Rank	GMAV (µg/L)	Species	Number of tests
1	0.06	Cladoceran	
		Ceriodaphnia dubia	5
2	0.11	Amphipod	
		Gammarus lacustris	1
3	0.15	Mysid	
		Neomysis mercedis	3
4	0.38	Stonefly	
		Pteronarcella badia	1
5	0.54	Cladoceran, Genus *Daphnia*	
		Daphnia pulex (SMAV = 0.30)	1
		Daphnia magna (SMAV = 1.0)	1
6	0.58	Stonefly	
		Claassenia sabulosa	1
7	0.60	Midge	
		Chironomus tentans	3
8	0.80	Crawling water beetle	
		Petodytes sp.	1
9	3.03	Bluegill	
		Lepomis macrochirus	6
10	6.0	Crayfish	
		Orconectes immunis	1
11	10	Stonefly	
		Pteronarcys californica	1
12	10.1	Salmonid, Genus *Oncorhynchus*	
		Oncorhynchus mykiss (SMAV = 7.5)	3
		Onchorynchus clarki (SMAV = 13.6)	4
13	138	Amphipod	
		Hyallela azteca	1
14	244	Lake trout	
		Salvelinus namaycush	1
15	274	Fathead minnow	
		Pimephales promelas	5
16	475	Channel catfish	
		Ictalurus punctatus	2
17	>806	Goldfish	
		Carassius auratus	1
18	>806	Snail	
		Aplexa hypnorum	1

Table 9. Eight families of freshwater aquatic animals recommended by USEPA (1985) for use in deriving the Final Acute Value (FAV) and representative species for which chlorpyrifos acute toxicity data were available.

Family	Animal
1. One Salmonid	Rainbow trout
2. Another family in Osteichthyes	Bluegill
3. Another family in Chordata	Fathead minnow
4. One family not in Arthropoda or Chordata	Amphipod
5. One insect family or any phylum not already represented	Stonefly
6. One planktonic crustacean	Cladoceran
7. One benthic crustacean	Crayfish
8. One insect	Crawling water beetle

Table 10. Ranked Genus Mean Acute Values (GMAV) from accepted acute toxicity tests on saltwater species used to calculate the saltwater FAV for chlorpyrifos.

Rank	GMAV (µg/L)	Species	Number of tests
1	0.04	Mysid	
		Mysidopsis bahia	3
2	0.69	Shrimp, Genus *Penaeus*	
		Penaeus aztecus (SMAV = 0.20)	1
		Penaeus duorarum (SMAV = 2.4)	1
3	1.2	California grunion	
		Leuresthes tenuis	6
4	1.5	Grass shrimp	
		Palaemonetes pugio	1
5	1.5	Silverside, Genus *Menidia*	
		Menidia menidia (SMAV = 0.5)	5
		Menidia peninsiluae (SMAV = 1.6)	9
		Menidia beryllina (SMAV = 4.2)	1
6	1.6	Rotifer	
		Brachionus plicatilis	3
7	2.7	Killifish, Genus *Fundulus*	
		Fundulus grandis (SMAV = 1.8)	1
		Fundulus similis (SMAV = 4.1)	1
8	5.2	Blue crab	
		Callinectes sapidus	1
9	5.4	Striped mullet	
		Mugil cephalus	1
10	7.0	Spot	
		Leiostomus xanthurus	1
11	188	Gulf toadfish	
		Opsanus beta	2
12	194	Sheepshead minnow	
		Cyprinodon variegatus	2
13	1991	Easter oyster	
		Crassostrea virginica	1

Table 11. Eight families of saltwater aquatic animals recommended by USEPA (1985) for use in deriving the Final Acute Value (FAV) and representative species for which chlorpyrifos acute toxicity data were available.

Family	Animal
1, 2. Two families in chordata	Silverside
	Striped mullet
3. One family not in phylum Arthropoda or Chordata	Eastern oyster
4,5,6. Three other families not in phylum Chordata	Brown shrimp
	Blue crab
	Pink shrimp
7. A mysid or penaeid	Mysid
8. One other family not already represented	Rotifer

CHRONIC TOXICITY OF CHLORPYRIFOS TO AQUATIC ORGANISMS

One chronic toxicity test for chlorpyrifos was evaluated and accepted. This test was for cladoceran *Ceriodaphnia dubia*. As a part of the same study, an acute test was conducted for *C. dubia*. The ACR generated in this study was added to the ACRs previously generated (Menconi and Paul 1994) and a new FACR was calculated (Table 12). USEPA (1985) guidelines specify that if the ACR values increase or decrease as the SMAVs increase, as the ACR values generally do with chlorpyrifos, only species with SMAVs close to the FAV should be used to calculate the FACR. Accordingly, the FACR value for chlorpyrifos was calculated as the geometric mean of the ACR values for cladoceran *Ceriodaphnia dubia* and mysid *Mysidopsis bahia*. The FACR was 3.5. The freshwater FCV was 0.014 µg/L and the saltwater FCV was 0.009 µg/L. These Freshwater and saltwater FCVs generated by Menconi and Paul (1994) were 0.02 and 0.01 µg/L, respectively. The freshwater and saltwater FCVs generated by USEPA (1986) were 0.04107 and 0.005620 µg/L, respectively.

Table 12. Acute-Chronic Ratio (ACR) values for freshwater and saltwater species for chlorpyrifos for which acute and chronic toxicity data were available.

Species	MATC (µg/L)	LC_{50}(µg/L)	ACR
Cladoceran *Ceriodaphnia dubia*	0.040	0.038[a]	0.95[c]
Tidewater silverside *Menidia peninsulae*	0.54	0.71[b]	1.3
Inland silverside *Menidia beryllina*	1.16	4.2	3.6
Mysid *Mysidopsis bahia*	0.003	0.040[b]	13.3[c]
Fathead minnow *Pimephales promelas*	5.23	249[a]	47.6
Fathead minnow *Pimephales promelas*	2.26	140[a]	61.9
Sheepshead minnow *Cyprinodon variegatus*	2.26	194[b]	85.8
Gulf toadfish *Opsanus beta*	2.28	520[a]	228

[a]LC_{50} and MATC from same test.
[b]Species Mean Acute Value: geometric mean of values from several tests on this species.
[c]ACR value used to calculate Final ACR value.

CRITERIA FOR CHLORPYRIFOS

The freshwater and saltwater FAVs for chlorpyrifos were 0.05 µg/L and 0.03 µg/L, respectively. The FACR for chlorpyrifos was 3.5. The freshwater and saltwater FCVs for chlorpyrifos were 0.014 and 0.009 µg/L, respectively . The freshwater CMC was equal to one-half the freshwater FAV, or 0.02 µg/L The saltwater CMC was equal to one-half the saltwater FAV, or 0.02 µg/L Freshwater and saltwater organisms should not be affected unacceptably if the one-hour average concentration of chlorpyrifos does not exceed 0.02 µg/L more than once every three years on average. The CCC is equal to the lowest of three values: the FCV, the FPV, or the FRV. Therefore, the freshwater and saltwater CCC values were 0.014 and 0.009 µg/L, respectively. Freshwater and saltwater organisms should not be affected unacceptably if the four-day concentration of chlorpyrifos does not exceed 0.014 µg/L and 0.009 µg/L, respectively, more than once every three years on average. The freshwater CMC and CCC generated by USEPA (1986) were 0.083 and 0.041 µg/L, respectively (Table 12). The saltwater CMC and CCC calculated by USEPA (1986) was 0.011 µg/L and 0.0056 µg/L, respectively. These WQC are for chlorpyrifos alone.

Table 13. CDFG and USEPA (1986) water quality criteria for chlorpyrifos to freshwater organisms

Reference	CMC	CCC
CDFG (this report)	0.02 µg/L	0.014 µg/L
USEPA (1986)	0.083 µg/L	0.041 µg/L

JOINT TOXICITY OF DIAZINON AND CHLORPYRIFOS

Two studies were conducted to evaluate the joint toxicity of diazinon and chlorpyrifos to the cladoceran *Ceriodaphnia dubia* (Bailey et al. 1997, CDFG 1999a). The toxicities of chlorpyrifos and diazinon appear additive (Table 14). An Additive Index (Marking 1985) between -1 and 1 (symmetrical about 0) indicates additivity (Table 14).

Table 14. Joint toxicity of diazinon and chlorpyrifos (96-h LC_{50} values in µg/L) to *Ceriodaphnia dubia*.

	Bailey et al. (1997)	CDFG (1999a,c; 1998b)
Chlorpyrifos alone	0.053, 0.055	0.038
Diazinon alone	0.32, 0.35	0.44
Chlorpyrifos in mixture	0.024, 0.020 (0.41 toxic unit)	0.02 (0.52 toxic unit)
Diazinon in mixture	0.23, 0.24 (0.70 toxic unit)	0.15 (0.34 toxic unit)
Total Toxic Units	1.11	0.88
Additive Index	-0.11	0.14

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